CHAPTER I
INTRODUCTION

1.1 Background

The telecommunications industry has undergone significant transformation, especially with the release of cellular technology's fifth generation, known as 5G New Radio (5G NR), which began to be deployed globally in 2020 [1]. This technology is designed to provide very high data transmission speeds, minimal latency, and large-scale connectivity to support human communications and the Internet of Things (IoT). In the context of an increasingly digital society, fast and reliable connectivity has become a fundamental need that supports various aspects of economic activity and quality of life. To meet these high-performance demands, 5G networks utilize higher frequency bands such as the 26 GHz spectrum, which offers very large bandwidth for ultra-fast data transmission [2]. Nevertheless, this frequency band also presents propagation challenges due to its short range and susceptibility to signal attenuation, thus requiring a much denser network of base stations. The implementation of 5G networks, therefore, presents significant challenges, especially related to the high capital investment required. The development of new Base Transceiver Stations (BTS) and the upgrade of existing network components require significant financial resources. In many cases, it is mandatory for mobile network operators to construct and oversee their own infrastructure independently. This often leads to duplicated spending, inefficient use of equipment, and slower progress in expanding the network. These problems are even more severe in developing countries like Indonesia, where limited government funding and challenging terrain make it even harder to roll out 5G networks quickly and fairly. Therefore, the implementation of Multi Operator Radio Access Network (MORAN) is needed, because it permits several operators to use the same RAN, equipment while using different spectrum. This approach is expected to reduce Capital Expenditure (CAPEX) and Operational Expenditure (OPEX), accelerate network deployment, and extend coverage especially in areas where building separate infrastructure is inefficient or too expensive.

Several studies on the implementation of 5G technology in Indonesia show various approaches that can reduce CAPEX and OPEX costs and accelerate network deployment. One of them is the Radio Access Network (RAN) spectrum sharing scheme analyzed in Banjarmasin City and Banjarbaru, which shows a reduction in investment costs of up to 50-67% with a three-operator sharing scheme. Economic analysis with parameters such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP) shows that this scenario is financially viable, with OPEX being the most sensitive parameter to investment feasibility [3]. However, the deployment of Dynamic Spectrum Sharing (DSS) in Bandung optimizes spectrum usage by dynamically utilizing the same frequency for 4G and 5G networks. This DSS not only reduces CAPEX and accelerates the deployment of 5G networks, but also provides efficiency in allocating bandwidth in real-time, thereby improving spectrum efficiency and operational costs. Analysis of the DSS using similar economic parameters showed investment feasibility with NPV of IDR35.39 billion, IRR of 13%, and PP for 5 years and 9 months [4]. In addition, research on 5G implementation at 2.3 GHz frequency in Bandung City shows that this technology is able to fulfill the needs of 5G networks by building 55 gNodeBs for downlink and 35 gNodeBs for uplink. The maximum data rate achieved is 684.84 Mbps on the downlink and 91.58 Mbps on the uplink, which is sufficient for 5G communication needs. The economic analysis also showed the feasibility of the investment with an NPV of Rp39.24 billion, an IRR of 8.90%, and a PP of 8 years and 7 months, as well as a Profitability Index (PI) of 1.12 [5].

These three studies underline the importance of sharing schemes such as RAN and DSS spectrum sharing in optimizing spectrum usage, accelerating 5G network deployment, and ensuring technical and economic feasibility in developing telecommunications infrastructure in Indonesia. However, the main weakness of these studies is that they have not considered the use of high frequencies, such as 26 GHz, which have greater potential to support 5G network capacity with higher speeds. The 26 GHz frequency, which offers greater bandwidth and more communication channels, will be the subject of future research updates to examine how this technology can increase network capacity and accelerate 5G adoption in Indonesia. In addition, this study will adopt the MORAN Sharing scheme to optimize the use of shared infrastructure without duplication of network elements.

This study aims to evaluate the feasibility of 5G infrastructure sharing schemes for mobile operators in Indonesia by examining three key aspects: technology, economy, and regulation. From the technological perspective, the study analyzes Coverage and Capacity based planning, particularly focusing on the integration of the 26 GHz frequency. The economic analysis includes a detailed evaluation of business feasibility by comparing non-sharing and sharing schemes, using financial metrics such as NPV to measure investment profitability, IRR to assess financial viability, PP to estimate the time needed to recover initial capital, and Sensitivity Analysis to understand the impact of cost and revenue fluctuations on project viability. Meanwhile, the regulatory aspect explores the extent to which current policies in Indonesia support or hinder infrastructure sharing, particularly in the context of high-frequency spectrum utilization. By combining these technical, financial, and regulatory evaluations, this study aims to provide strategic insights and recommendations for operators in adopting shared infrastructure models to accelerate and optimize 5G deployment in Indonesia.

The findings of this study have been published and presented as part of its development at The 2025 IEEE International Conference on Industry 4.0, Artificial Intelligence, and Communication Technology (IAICT) which demonstrates noteworthy advancements in this discipline.

1.2 Problem Identification

In this study, the problem formulation is how to overcome the obstacles of high investment costs in the implementation of 5G technology using 26 GHz Frequency in Indonesia, to satisfy the growing need for mobile broadband services with high speeds, and evaluate the technical, economic and regulatory feasibility of implementing infrastructure sharing schemes between mobile operators. More detailed problem derivatives include:

1. High-capacity 5G NR services using 26 GHz frequency have not been implemented in Indonesia. Operators will not be able to meet people's increasing need for mobile broadband, which will ultimately cause the country's economy to not grow.
2. Cellular operators have difficulty deploying 5G networks because investment costs are very expensive, causing technological developments to be disproportionate to human needs.
3. Analysis needs to be carried out to evaluate the extent to which existing regulations can support infrastructure sharing schemes between cellular operators.
4. From the explanation of the problems above, a study was carried out regarding the feasibility of planning a 5G NR network from a technical, economic and regulatory perspective to resolve these problems.

1.3 Objective

This study's objective is to evaluate the technical and economical feasibility of deploying 5G on 26 GHz frequency in dense urban, urban, and sub-urban areas through an infrastructure sharing scheme between operators. The main focus is to calculate the infrastructure requirements such as gNodeB, and evaluate the financial potential through CAPEX, OPEX, NPV, IRR, and PP analysis. This study also analyzes the impact of regulations on the implementation of the sharing scheme, to assess its support for 5G implementation in Indonesia. More detailed objective include:

1. Calculate the link budget, path loss, and number of gNodeB required to ensure adequate coverage and capacity on the 26 GHz frequency in dense urban, urban, and sub-urban areas.
2. Evaluate techno-economic potential of infrastructure sharing schemes at the 26 GHz frequency for 5G networks. This includes calculating CAPEX, OPEX, NPV, IRR, and PP to understand the business feasibility for mobile operators.
3. Measuring the impact of existing regulations on infrastructure sharing between cellular operators. This will help in determining the extent to which regulations support or hinder the implementation of sharing schemes on infrastructure sharing for 5G implementation.

1.4 Scope of Work

To strengthen the points of concern, the various problems solved in this research are limited to the following:

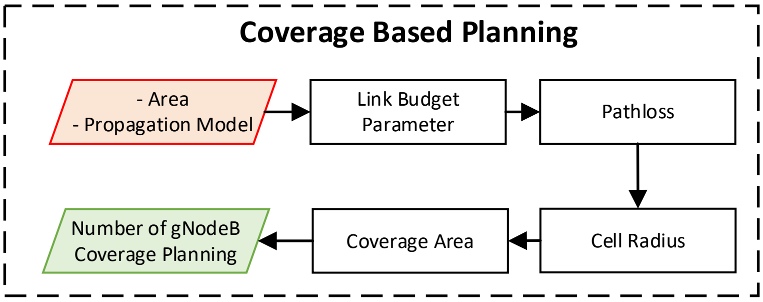
1. This study focuses on three different types of areas, namely dense urban areas in Mampang Prapatan, South Jakarta; urban areas in Beji, Depok; and suburban areas in Ciampea, Bogor Regency.
2. The cellular technology in this study is 5G using a 26 GHz frequency, with the Urban Micro (UMi) propagation model for the Outdoor to Outdoor (O2O) scenario and Line Of Sight (LOS) conditions.
3. The infrastructure sharing model analyzed in this research is Multi Operator Radio Access Network (MORAN) Sharing.
4. The object of this thesis research is Mobile Network Operators (MNO). The number of cellular operators is limited to three operators, namely Telkomsel, Indosat Ooredoo Hutchison, XLSMART.
5. Techno-economic calculations are carried out using Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP) in the non-sharing and sharing scenarios.

1.5 Research Method

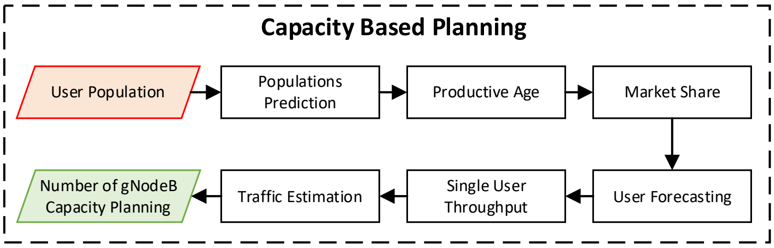
This study assesses the viability of deploying 5G networks in Indonesia using a techno-economic analysis methodology, especially with the MORAN sharing scheme. The method consists of three main parts, namely Capacity and Coverage based planning, Economic Feasibility Analysis and Regulation Analysis which compliment one another in providing a complete picture of the potential and challenges of 5G network implementation.

1. Capacity and Coverage based planning Approach

   Capacity and Coverage based planning is used to determine infrastructure needs based on data traffic and coverage area.



   The research method used in 5G network Coverage based planning is carried out through several structured stages. First, population and geographic data of the research area were collected according to trustworthy authorities, such the Central Bureau of Statistics, to determine the network requirements in the region under study. Next, related literature, including technical standards from ITU, IEEE, and 3GPP, are used as references in the planning process. An Urban Micro (UMi) propagation model with line-of-sight (LOS) conditions was selected in accordance with 3GPP TR 38.901 standard to estimate signal coverage based on 26 GHz frequency and 100 MHz bandwidth. This propagation model is used to calculate link budget parameters, including receiver sensitivity, transmit power, and fading margin. Furthermore, the link budget parameters are used to calculate the pathloss value, which represents the signal attenuation during propagation within the coverage area. Based on the calculated pathloss value, the cell radius is determined by considering an operating frequency of 26 GHz and a bandwidth of 100 MHz. This cell radius was used to calculate the coverage area of each cell using a geometric approach. Furthermore, the number of gNodeB sites needed to cover the full study area is calculated by dividing its total area by the coverage area per cell. Based on geographic considerations and signal propagation characteristics at the high frequencies used, the computation's findings yield an estimate of the ideal number of gNodeB sites to satisfy the network coverage requirements in the study area.



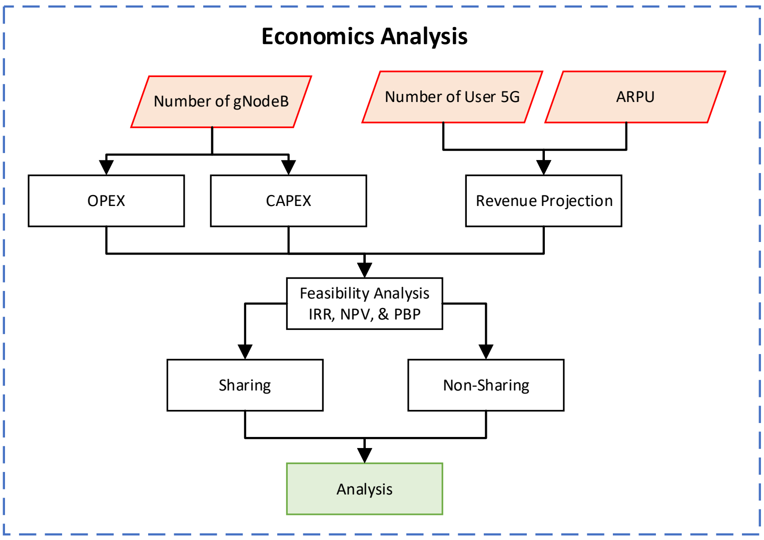
In conducting 5G network Capacity based planning, it is important to conduct demand forecasting to estimate the future demand for 5G services in the target region. This step involves analyzing historical data on telecom usage, population growth trends, and adoption rates of new technologies. The forecasting process considers various factors such as economic conditions, technological advancements, consumer behavior, and potential applications of 5G technology. The goal is to project the expected number of users, data traffic growth, and the types of services that will be in demand. Furthermore, estimating the number of people anticipated to adopt 5G services over the next five years is the first step in designing 5G network capacity. Based on population prediction statistics, the estimated number of subscribers takes into account each operator's market share in addition to productive age groups. In order to more precisely determine the anticipated number of users, the Bass Model method is used which divides users into two categories, namely innovators and imitators, to describe the pattern of adoption of new technologies. After obtaining the projected number of users, the next step is to estimate the traffic that will occur by calculating the average throughput per user. The results of this traffic estimation will provide an overview of the network capacity required to support future user demand. Thus, proper Capacity based planning can ensure that 5G networks can operate optimally and meet traffic needs without capacity shortages, as well as support maximum service quality in the designated area.

Additionally, the number of gNodeB sites derived from the computation that produced the highest total between coverage and capacity-based planning was used in software simulations. In this simulation, software simulation was used to model the distribution of gNodeB sites that had been calculated previously, with the aim of measuring network performance, including the Synchronization Signal Reference Signal Received Power (SS-RSRP) and Signal-to-Interference Noise Ratio (SINR) parameters. These measurements are important to evaluate the signal quality received by users in the research area. The results of this simulation provide information related to signal distribution, network quality, and potential interference problems that may occur, as well as ensuring that the planned 5G network can function optimally in a predetermined area.

2. Multi Operator Radio Access Network (MORAN) sharing scheme method

   The MORAN sharing scheme is a form of infrastructure sharing in which multiple mobile operators share the physical elements of the Radio Access Network such as gNodeB and antennas, but retain separate control over their frequency spectrum. In MORAN, network elements such as gNodeBs and other access equipment are shared by operators, while the core network elements and spectrum remain exclusive to each operator. This scheme enables operational and investment cost efficiencies, while supporting independent network management by each operator. MORAN is highly relevant for 5G deployment in Indonesia, especially to address the challenges of high infrastructure costs and coverage in large areas.

3. Economic Feasibility Analysis



   To assess the financial viability of implementing 5G with sharing and non-sharing schemes, an economic feasibility analysis was carried out. In this analysis, NPV, IRR, and PP are the primary metrics. The total project cash flow's current value is determined using the Discounted Cash Flow (DCF) approach, which serves as the foundation for evaluating the risks and rewards of investments. Additionally, the efficiency of project profitability in relation to the initial investment is measured by the Profitability Index (PI). Sensitivity to variables including shifts in OPEX, CAPEX, and revenue forecasts is also included in the economic analysis. Finding the elements that have the biggest impact on the project's financial feasibility is crucial. As such, the analysis not only evaluates cost-efficiency, but also provides strategic recommendations to manage risks and improve the sustainability of network implementation.

4. Regulatory Review

   A regulatory review is conducted to assess the adequacy and compatibility of existing telecommunications regulations in supporting infrastructure sharing schemes like MORAN. This includes an analysis of Indonesia's regulatory framework, such as the Telecommunications Law, licensing requirements, and infrastructure sharing policies. The review identifies gaps and potential improvements needed to create a conducive environment for shared infrastructure implementation. Collaboration between government agencies, operators, and industry stakeholders is emphasized to establish clear guidelines and incentives for sharing schemes, ensuring compliance with national objectives for equitable and efficient 5G deployment.

1.6 Hypotheses

The development of 5G network technology offers a great opportunity for mobile operators to improve service quality and operational efficiency. However, a major challenge faced by operators is the high investment cost to build infrastructure and extensive coverage, especially in underserved areas. In this context, the MORAN scheme emerges as a solution that allows multiple operators to share radio infrastructure, reduce investment costs, and expand coverage without having to build separate networks [3]. On the other hand, the implementation of MORAN schemes in Indonesia must also comply with regulations governing infrastructure sharing, and ensuring that service quality is maintained. Based on this, this study formulates the following hypotheses:

1. 5G Network Technical Analysis

   Optimization of 5G network capacity and coverage through technical variables such as throughput, gNodeB density, SINR, and RSRP will enhance user experience. Efficient frequency spectrum utilization, high modulation, and adequate bandwidth allocation contribute to the network's ability to serve more users with stable signal quality.

2. Cost Efficiency through MORAN Scheme

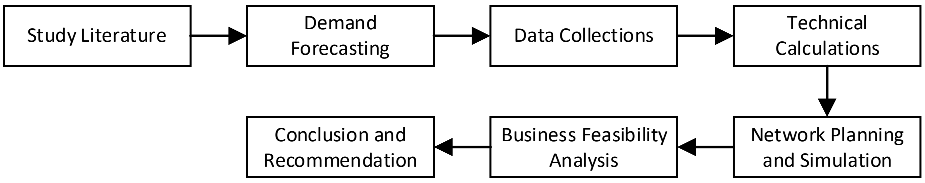
   Implementation of RAN sharing schemes in the context of MORAN can reduce CAPEX and OPEX costs for mobile operators, while maintaining optimal network quality. This cost efficiency can be evaluated through economic metrics such as IRR, NPV, and PP. The results of this analysis show the potential for saving infrastructure development costs and increasing operator profitability, especially in areas with small market shares or in areas that are not yet covered by the network.

3. Regulation in MORAN Scheme

Regulations governing the MORAN scheme will influence the implementation and success of this model in Indonesia. The adoption of policies that support infrastructure sharing and frequency sharing, while maintaining service quality, can promote operational efficiency and ensure compliance with technical and legal standards. Appropriate regulations will ensure equal access for operators, avoid monopolies, and increase the adoption of 5G technology across regions, including underserved areas.

This hypothesis aims to explore the relationship between capacity, coverage, cost efficiency, and regulation in the implementation of the MORAN scheme in 5G networks in Indonesia, as well as its impact on network performance and operator business sustainability.

1.7 Research Methodology



In general, this research is conducted using an experimental method with the following sequence:

1. Study Literature

   A review of relevant theories related to 5G technology is necessary, utilizing various references such as books, previous research papers, and journals that support the design of 5G telecommunications networks from both technical and economic perspectives.

2. Demand Forecasting

   Before data collection, it is crucial to conduct demand forecasting to estimate the future demand for 5G services in the target area. This step involves analyzing historical data on telecommunications usage, population growth trends, and the adoption rate of new technologies. The forecasting process considers various factors such as economic conditions, technological advancements, consumer behavior, and potential applications of 5G technology. The goal is to project the expected number of users, data traffic growth, and the types of services that will be in demand. This step provides a foundation for determining the network capacity and the necessary infrastructure to meet future demand.

3. Data Collections

After conducting the demand forecasting, the next step involves data collection from telecommunications service providers and other relevant entities. Data processing will be done to determine the initial market capacity and estimate the initial number of customers based on the design. The data collection will include information on existing infrastructure, market share, customer numbers, ARPU (Average Revenue Per User), total population, population density, population growth rate, and area size. Additionally, relevant regulations pertaining to this research must also be collected.

4. Technical Calculations

   After obtaining and processing the data that support the research, the next step is to proceed with the calculation process to identify the projected number of users, final market capacity, traffic demand requirements, spectral efficiency, link budget, coverage, and path loss. This approach is carried out in two ways: the capacity approach and the coverage approach.

5. Network Planning and Simulation

   The design and simulation process uses simulation software to simplify calculations and obtain key parameters, namely RSRP and SINR, to assess signal quality. The number of gNodeBs used in the network simulation is determined by the higher value between the coverage and capacity based planning, ensuring both service area and user demand are adequately met.

6. Business Feasibility Analysis

   Analysis is carried out after the calculation, design and simulation processes are complete. This analysis process aims to discuss the economic deployment of 5G telecommunications networks with non-sharing and investment cost sharing scenarios for modeling in South Jakarta, using the IRR, NPV and PP parameters. In addition, sensitivity analysis will be added to determine which parameters are most impact or sensitive to the business.

7. Conclusion and Recommendation

   In conclusion, this study highlights the importance of regulatory analysis through operational and standardization approaches. The operational analysis will ensure the 5G planning in Mampang Prapatan, Beji and Ciampea aligns with Indonesian telecommunications regulations, while the standardization analysis will assess compliance with national standards. As regulatory adjustments are needed at both national and international levels for successful 5G deployment, this study aims to provide recommendations addressing technical, economic, and regulatory challenges for the effective implementation of 5G NR networks in Indonesia.